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A SURVEY OF X-RADIATION FROM COLOR TELEVISION SETS IN THE WASHINGTON, D. C. METROPOLITAN AREA

National Center for Radiological Health
Rockville, Maryland

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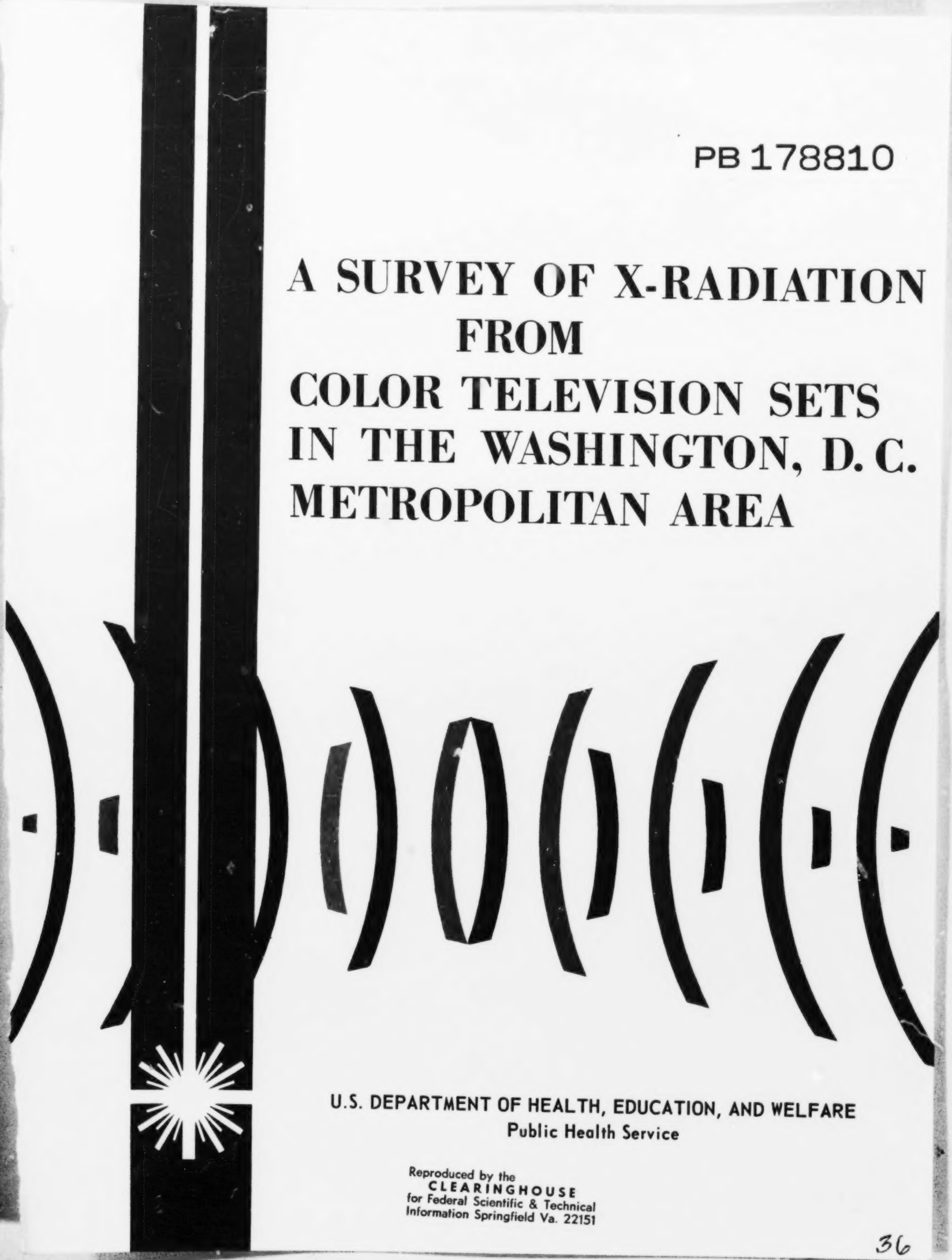

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

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by

Technical Services Branch

March 12, 1968

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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National Center for Radiological Health
Rockville, Maryland 20852

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ERRATA

TABLE VI, Page 3, Case 44, X-Radiation Exposure Rates in mR/hr-Film:

should read 3.1 mR/hr instead of 51.00 mR/hr

TABLE VI, Page 4, Footnote 4:

should read 0.8 mR/hr instead of "greater than 0.5 mR/hr"

FOREWORD

This report presents findings of a survey of X-radiation emissions from color television receivers conducted by the National Center for Radiological Health with the active cooperation of the Electronic Industries Association and the individual manufacturers. The survey was undertaken after a pilot survey in Pinellas County, Florida, designed to measure the effectiveness of a shunt regulator correction program, indicated radiation emissions were occurring from components common to the industry. The purpose of this survey was to obtain information on the X-ray emission of television receivers of all manufacturers included in a sample of color television receivers in use in the homes of Public Health Service employees in the Washington, D. C. area. The sample was obtained by means of a questionnaire addressed to Public Health Service employees in the Washington, D.C. Metropolitan Area, who were asked to volunteer their sets for radiation measurements.

With the assistance of the Electronic Industries Association, technical representatives from each of the manufacturers whose sets happened to be in the sample were asked to provide technical support for the survey team.

The individual manufacturer representatives assisted in obtaining set identification and made measurements of the household line voltage and the operating high voltage in the television receivers examined. The industry representatives also replaced certain high voltage tubes and made other adjustments to reduce radiation emissions in any set exceeding the level recommended by the National Council on Radiation Protection and Measurements.

The results given in our report are applicable to the sample of television receivers in the Washington Metropolitan Area and may not be representative of national X-radiation emission from television receivers.

In addition to data on radiation levels, the survey provided information as to the causes of radiation emissions and corrective action which can be taken by industry to prevent unnecessary radiation exposure to the public.

We hope that the report will be useful to the industry and other official agencies who are planning future activities and programs relating to the control of radiation emissions from electronic products.

James G. Terrill, Jr.
Center Director

A Survey of X-radiation from Color Television Sets in the Washington, D. C. Metropolitan Area

INTRODUCTION

The Public Health Service conducted a survey of X-ray emissions from a sample of color television sets in the Washington, D.C. Metropolitan Area with active industry cooperation. Previous tests conducted by the Public Health Service had shown that X-radiation from color television receivers is related to (1) certain operating parameters, primarily high voltage, (2) excessive emission from components, and (3) inadequate shielding of components emitting X-radiation (Ref. 1 & 5). There were a number of considerations which led to the interest in determining whether X-radiation emission was an industry-wide problem, including the knowledge that all color TV sets contained high voltage rectifiers and picture tubes which could produce X-rays, and that many of the sets had shunt regulator tubes which could also produce X-rays. In many instances, the components originating in both domestic and foreign plants are used on an industry-wide basis. Likewise, only a few manufacturers provide the basic materials from which many components are produced. It was also expected that excessive emissions might be related to actions by the servicing industry and to variations in local power supplies which would tend to affect the sets of all manufacturers.

In addition to these technical reasons, surveys made up to this time had largely concentrated attention on one manufacturer. In some other instances in which a very small number of sets had been tested, published comments had indicated some receivers showed excessive X-radiation emissions whereas it

was probable that these evaluations had not been based upon sufficient data to justify a firm conclusion. In order to obtain a sample which might provide more information on receivers of many manufacturers, and within the logistic capabilities of the National Center for Radiological Health, employees of the Public Health Service in the Washington, D.C. area were asked to volunteer their color television sets for radiation measurements. The owners of the sets were requested to complete a questionnaire with specific information on make and picture tube size. The request led to the availability for survey purposes of 1,124 color television receivers of a variety of brand names and models from 20 domestic and five foreign manufacturers.

SURVEY METHODS AND OPERATION

Protocol

Visits to homes to obtain X-radiation emission measurements and other essential data were started on December 16, 1967. As many as nine teams, normally consisting of two representatives from the Public Health Service and two representatives from a manufacturer, were in the field during the survey. Appointments were arranged a day or two in advance to permit approximately three home visits every two hours. A maximum of 14 visits per day per team was possible with the average being seven per day.

Representatives from 20 domestic manufacturers, five foreign manufacturers, and two retail distributors assisted in the surveys. Manufacturers representatives assisted in obtaining the model and serial numbers of the receiver, and the brand and code number of the shunt regulator, rectifier, and picture tubes. Representatives also made measurements of household line voltage and the operating high voltage. Industry representatives were scheduled to participate only in those surveys involving sets which they manufactured or distributed.

Each set was assigned a code number which was recorded on the report forms completed for each set. The code number was placed for identification purposes on the shunt regulator and rectifier tubes obtained when these tubes were replaced in the set. To facilitate survey scheduling with the appropriate manufacturer's or retailer's service representative and data tabulation, receivers were grouped as follows: (1) as sets made and sold under one manufacturer's name or (2) as sets sold under one or more brand names produced by one or more manufacturers.

The objectives of the survey were:

1. To obtain X-ray emission data on a variety of makes and models of color television sets operating in the Washington area.

2. To test procedures for and to determine the feasibility and usefulness of more representative and extensive surveys of color television receivers.

3. To provide information on possible sources of X-radiation which could be used by manufacturers or service organizations to prevent or correct excessive X-radiation emissions.

As a corollary to the survey, corrective service was provided for any set having X-radiation emissions in excess of the National Council on Radiation Protection and Measurements' recommendation "that the exposure rate at any readily accessible point 5 cm. from the surface of any home television receiver shall not exceed 0.5 mR per hour under normal operating conditions." (Ref. 2).

In the homes, X-radiation emission from surfaces of the set was measured, using a survey instrument developed by the National Center for Radiological Health. (Ref. 3). Prior to the survey of the receiver, the person interviewed in the home was requested to observe the picture and determine whether the receiver was operating in a condition as normally viewed. The X-radiation measurements were then recorded on the report under such home operating conditions. If X-radiation was detected, the set was adjusted to minimum brightness and then to maximum brightness so additional measurements could be made and recorded under those conditions. If the set, as measured by the instrument, was emitting X-radiation in excess of 0.5 mR/hr under home operating conditions, and if a radiographic film could be applied to the set, permission for radiographic film use was requested. Films were also placed on surfaces of a number of receivers measuring less than 0.5 mR/hr in order to secure film information for lower X-ray emission levels. The film was applied to the area of X-radiation emission located by the survey instrument. On some receivers, films were exposed on more than one surface. A timer was used to record the set operating times while 37 films were exposed. In 28 films where timers could not be used, the householders or the survey team kept a record of the exposure time.

Survey Instrument

The instruments used in the survey were designed and constructed expressly for the purpose of performing in-home measurements of X-radiation emissions from color television receivers. The radiation sensitive element of this instrument is an array of six Victoreen type 1B85 Geiger-Mueller tubes connected to a common high voltage supply. Individual solid state circuits measure the current through each detector. The outputs of the six read-out circuits are connected to the input of the meter circuit in such a manner that the meter indicates only the reading of the detector with the highest output. The circuitry provides the detection area of six Geiger-Mueller tubes and the background and calibration sensitivity of one tube. The large sensitive detection area provided by the six tubes allowed a surveyor to make a complete traverse of all set surfaces in ten minutes. The instrument was easily handled in any position with one hand. The location and approximate size of radiation beams could be estimated by depressing a switch which turned off all detector tubes except the end one. Survey instrument response was checked daily at the Electronic Products Radiation Laboratory prior to a survey team's departure. A Thulium 170 check source was moved the entire length of the instrument to check for the proper response of each of the six Geiger-Mueller tubes.

Calibration

For the purpose of the Washington survey, the survey instrument was calibrated with an X-radiation beam from a 6EF4 shunt regulator tube operated with 25 kVDC between cathode and anode which uniformly irradiated the entire 12.81 cm^2 (1.83 cm. by 7.0 cm.) cross-section of one Victoreen type 1B85 Geiger-Mueller detector at exposure rates between

0 and 12.5 mR/hr. The half-value layer of this X-ray beam was 0.50 mm of aluminum equivalent. The exposure rates for the calibration X-ray beam were determined by a Victoreen model 440 RF Survey Meter the response of which had been found to be essentially independent of photon energy for X-rays from sources with accelerating voltages from 20 to 60 kVp and with first half-value layers (HVL's) of 0.40 to 2.00 mm of aluminum equivalent. This secondary system in turn had been calibrated by means of a General Electric Maximar 100 Self-Rectified therapy X-ray machine, and a Victoreen Type 326, 10 roentgen ionization chamber having National Bureau of Standards calibration for lightly filtered X-rays (Ref. 4). With the Geiger-Mueller survey instrument, the same meter response will result from an exposure rate of approximately 6.5 mR/hr over an area of 1 cm^2 or approximately 650 mR/hr over 0.01 cm^2 (1 mm by 1 mm) of the instrument detector. The instrument response does not require an area correction if the X-ray beam uniformly and completely irradiates one or more of the detectors. The survey protocol was developed to provide a reasonable interpretation of the National Council on Radiation Protection and Measurements' recommendation. The "exposure rate at any readily accessible point" was interpreted as the exposure rate averaged over the 13 square centimeter sensitive area of a single Geiger-Mueller tube, the smallest area measurable by available instrument components meeting the other requirements for use in the home survey.

Film

When the survey instrumentation indicated X-radiation exposure rates above 0.5 mR/hr, or when lower X-radiation emissions were to be studied and permission was given by the owner, radiographic film techniques were used as a supplementary survey technique. Permission was generally given for use of film on any side except over the picture tube. In some instances, the team leader made the judgment not to use the film because (1) long exposure times were necessary or (2) it was determined exposure time for the film could not be accurately recorded. In some cases the film could not be exposed because the film pack would have covered ventilation holes for an excessive length of time, possibly resulting in an overheating of the receiver. The film pack technique provided additional documentation on the size, shape, and possible source of the X-radiation emission as well as an additional measurement of exposure rate.

The film was placed against the surface of the set covering the area of highest survey instrument reading for the receiver. The film was held in position with masking tape in direct contact with the cabinet. The advantage of the attachment procedure was that it was convenient and did not damage the receiver. In most cases, the correction of X-ray exposure rates for placement of the film against the set instead of at 5 cm. from set surface was insignificant. In most cases an elapsed time meter was used to measure the total number of hours of operation of the set during the film exposure. The timer was connected in series between the wall socket and the television receiver. No internal connections were required to the set and the timer did not affect the operation of the receiver in any way. The set could be used normally throughout the test period, which

frequently amounted to several days. The timer was accurate within the limits of line frequency and could be read to 0.1 minute. The survey instrument averaged the X-radiation over an area of 13 cm^2 and might not have properly recorded the location of a small intense beam of X-radiation. Therefore, in some cases the film may not have covered the surface where the most intense exposure occurred. The film dosimetry packs contained two 14" x 17" films, one of high sensitivity (Kodak Type KK) for recording low radiation exposures, (10 mR to 200 mR) and the other of a lower sensitivity (Kodak Commercial) (50 mR to 60,000 mR) for recording higher exposures. These two films exhibit a satisfactory degree of overlap from 50 mR to 200 mR. The range of measurable X-radiation exposures for the combined package is from approximately 10 mR to over 60,000 mR. Film energy dependence for X-radiation expected from components operated in the observed high voltage range may result in an underestimate or overestimate of the true exposure rate by a factor of two. The highest exposure rate recorded by film during the survey was about 369 mR/hr. Since the X-radiation exposure recorded on some of the sensitive films was more than 200 mR, it was necessary to obtain optical density measurements from the commercial film. The more sensitive KK film was always placed closest to the TV receiver, the same position relative to the source of X-radiation used in the film calibration procedure. Instrument measurements of exposure rate were used to estimate the minimum time required to produce an exposure of 10 mR, the lower limit for optical density measurements on the film.

The exposed films were opened and loaded into a multiple film developing rack in complete darkness. They were then developed in fresh Kodak Rapid X-ray developer for five minutes at 20°C. During development the films were agitated every 25 seconds by two-second bursts of nitrogen bubbles.

After development was complete, the films were placed in Kodak Liquid Stop Bath for one minute and then fixed for ten minutes in Kodak X-ray Fixer. The films were then washed for 30 minutes in clear running tap water, dipped in Kodak Photo-Flo solution for one minute and dried in a hot-air drying chamber (Ref. 6).

The gross optical densities of the films were determined by using a MacBeth Ansco Densitometer, Model 12A, Serial No. 1350 with a 4 mm diameter light beam aperture. The densitometer was calibrated for an optical density range of 0.00 to 4.00 using the manufacturer's step wedge. Each gross optical density was converted to net optical density by subtracting a background fog and base density, determined from unexposed control films.

The conversion of net optical density units to X-ray exposure rate in terms of mR/hr is based on a table of values obtained for the National X-ray Exposure Study (Ref. 7). The conversion from net optical density to X-ray exposure is done in two steps. First, all densities are converted to the exposure that would have been required from cobalt-60 gamma rays. The cobalt-60 equivalent exposure is then converted to X-ray exposure by multiplying the former by 0.15, an average energy dependence factor for X-radiation that has a first half-value layer of 0.5 mm of aluminum. The reported film exposure rates are those calculated from the maximum net optical density measurement on the film within the optical density calibration range for the film used, either KK or commercial.

The geometry, uniformity, and quality of the X-radiation beam can produce significant differences between film and survey instrument exposure rate results. Recorded film exposure rates were based on the optical density

at the point (4 mm diameter) of highest density on the film. Film exposure readings averaged over an area more nearly approximating the sensitive area of the instrument would be expected to give exposure rates comparable to the survey instrument readings when all other factors are equal.

The Geiger-Mueller survey instrument responds to the average X-radiation intensity over a rectangle approximately 7.0 cm by 1.8.cm. If the field intensity is not uniform over this rectangle (as in the case for most films), the Geiger-Mueller survey instrument will probably indicate a lower value than the film.

Data Collection and Analysis

In addition to the X-ray emission levels measured for each set, estimates of the area of the X-radiation field and location of the center of the field on the set surfaces were entered on the survey report form. Information concerning the date of purchase and whether or not the set had been recently serviced was obtained from the receiver owner and recorded.

If a film pack was utilized, the film report form was completed. The location on the set and exposure start and stop times were entered on the film instruction form attached to each film pack. If a film pack was utilized, the receiver code number, the location on the set, the exposure start and stop times were recorded on a form attached to each film pack.

Limited information on viewing habits was obtained through discussion with household members while the survey measurements were being made. The formal interview technique was not employed so as to avoid extension of the time required for the home visits.

State and local health or other agencies interested in conducting surveys of their own may obtain additional information concerning procedures, forms and instrumentation used in the Washington Metropolitan area survey by writing the National Center for Radiological Health, 12720 Twinbrook Parkway, Rockville, Maryland 20852.

RESULTS

X-Radiation Emissions

Some X-radiation emission was detectable from a variety of makes and models of 1,124 color television receivers surveyed (see Table I). Table II gives the distribution of color TV receivers by the highest X-radiation exposure rates as measured by the NCRH survey instrument under home operating conditions. X-radiation emissions were not detected on 856 receivers. Exposure rates at or above 0.04 mR/hr were recorded for 268 receivers, with 202 of the 268 showing X-ray emissions of between 0.04 mR/hr and 0.5 mR/hr. Thus, 1,058 sets were within the recommendation of the National Council on Radiation Protection and Measurements, as interpreted for purposes of this survey. Of the 66 sets having X-radiation levels at or above 0.5 mR/hr, 40 indicated levels at or above 1.0 mR/hr, and 2 sets exceeded 12.5 mR/hr, the full scale reading of the survey instrument.

For the 268 sets at or above 0.04 mR/hr, X-radiation emissions were observed on six sides of ten receivers, on five sides of 18 receivers, on four sides of 22 receivers, on three sides of 32 receivers, on two sides of 57 receivers, and on one side of 129 receivers. Sixty-eight surveys measured the highest X-radiation levels at the left, 74 at the back of the television set, and 54 measured the highest level at the

front. Over 20 percent of the sets with levels greater than 0.04 mR/hr had the highest X-radiation emission from the front.

Of the 66 sets exceeding the 0.5 mR/hr reading, X-radiation emissions were detected on six sides of seven receivers, on five sides of eight receivers, on four sides of nine receivers, on three sides of twelve receivers, on two sides of sixteen receivers, and on one side of fourteen receivers.

Table III shows the location of the highest X-radiation level measured on the sets above the instrument's lower detection limit of 0.04 mR/hr. For the 66 sets equal to or exceeding 0.5 mR/hr, the location of the highest level measured was as follows: Bottom - 11, Left (of viewer) - 20, Top - 2, Front - 12, Right (of viewer) - 1, and Back - 20.

In the survey, 70 film packs were exposed on 55 receivers, 45 of which were found with X-radiation emissions at or above 0.5 mR/hr by the survey instrument. Exposure rates measured by the radiographic film technique ranged from 0.12 to 369 mR/hr as shown in Table VI.

Observed Operating Parameters

The survey provided data on line voltage and operating high voltage because of the importance of these parameters in the production of X-radiation (Ref. 5). These measurements were made by the manufacturers' representatives in the home. The line voltage measured ranged from 107 volts to 129 volts. The line voltage observed most often was 120 volts. The operating high voltage of a receiver can vary with line voltage depending on the degree of regulation provided by the circuit design.

The maximum variation in line voltage could produce a 20% change in the operating high voltage of a receiver.

Table IV shows the operating high voltage measurements on 808 receivers and the X-radiation emissions from these sets by high voltage intervals of 1 kV over the observed range of 18 kV to 34 kV. Some sets operating well below the observed average high voltage level emitted excessive X-radiation. However, as theory suggests, there is a general increase in the propertion of sets exceeding the 0.5 mR/hr X-radiation exposure rate as operating voltages increase.

Comparison of Measurements

Comparison of film pack and survey instrument measurements of X-radiation exposure rates are shown in Table VI. For 70 films, 58 valid comparisons could be made with survey instrument measurements of exposure rate. The film gave higher values than the instrument in 48 comparisons, lower values in 10 cases.

Factors Affecting X-radiation Emission

The basic receiver designs identified in the survey can be classed as circuit designs with or without high voltage shunt regulator tubes. High voltage measurements were made by mauufacturers' representatives and properly recorded on the report form on 226 out of the 268 sets found to be emitting X-radiation at or above 0.04 mR/hr.

The average observed high voltage for the 181 receivers with a shunt regulator tube, producing X-radiation at or above 0.04 mR/hr was 25.8 kV; the average rated voltage for these receivers was 24.4 kV. Eighty-two of the 181 receivers exceeded 26.5 kV.

For the 45 receivers not having a shunt regulator tube and producing measurable X-radiation, 27 had a high voltage reading above 27 kV which was the average value observed for such receivers. Table VII gives the distribution of the X-radiation exposure estimate measured for the year of purchase. Detectable X-radiation was observed regardless of the age of the sets. The survey did not provide detailed information on the amount of servicing, including replacement of components. A service adjustment within the 2-month period prior to the survey was reported for 24 of the 66 sets with exposure rates above 0.5 mR/hr. The average operating voltage for these 24 sets was 27.5 kV.

Source of X-radiation

The probable sources of X-radiation were determined from a review of the instrument measurements and the patterns formed on film. Figure 1 shows four patterns typical of exposed film packs. The probable primary sources of X-radiation emissions were identified as the high voltage shunt regulator tube, the high voltage rectifier tube, and the picture tube. In the 55 sets studied with film, the shunt regulator tube was identified as the probable primary source in 30 of the receivers, the picture tube in nine, a combination of the shunt regulator and picture tube in six, and the rectifier tube in eight other receivers. In two sets, no specific source could be identified.

Corrective Servicing

Each receiver with X-radiation emission above 0.5 mR/hr was serviced by the manufacturer's representative by replacing components and/or adjusting the operating high voltage to the recommended operating level. The set was then resurveyed for X-radiation emission to ensure that the corrective servicing had reduced the level below 0.5 mR/hr. The high voltage was

A. High exposure rate from multiple sources, picture tube, and shunt regulator.

B. Pattern of bottom emission from a shunt regulator tube.

C. A typical pattern from multiple sources.

D. Back pattern from a shunt regulator tube.

Figure 1 Photographs of Radiographic films exposed to X radiation from color television receiver

set to the value recommended by the manufacturer's representative for the line voltages as measured at the time of survey.

In one case the corrective servicing included the adjustment of high voltage, replacement of a tube, and the addition of shielding. The adjustment in operating high voltage and replacement of the shunt regulator tube reduced the X-radiation exposure rate below 0.5 mR/hr. It was not possible to detect any X-radiation from the set with the addition of shielding around the high voltage cage.

The servicing adjustments included 29 tube replacements for 27 of the 66 sets at or above 0.5 mR/hr. Two rectifier tubes type 3A3A were replaced. Twenty-seven shunt regulator tubes of type 6BK4, 6BK4A, or 6BK4B were replaced. For 36 of the 66 sets above 0.5 mR/hr, high voltage adjustments alone reduced radiation to 0.5 mR/hr or lower as measured by the survey instrument. Three receivers did not have a service adjustment recorded.

Exposure Parameters in the Home

The survey provided some data on viewing habits (Table V) of 2,311 individuals in 741 households: 743 household members viewed television from less than eight feet. Three hundred and eighty persons stated they viewed color sets in excess of 30 hours per week. Approximately 20 percent of the individuals under 15 years of age view color television more than 30 hours per week. Information stated by the person interviewed in the home indicated 328 of 547 viewers under age 15 view television at less than eight feet and 48 at distances under four feet.

DISCUSSION

The survey demonstrated that the industry is capable of producing sets which do not emit excessive amounts of X-radiation. More than three-fourths of the sets surveyed showed no detectable X-radiation emission in spite of the fact that the instrumentation could record X-radiation at levels approximately twice the normal radiation background in homes.

The survey was developed for the purpose of determining whether the color television X-ray emission problem was of an industry-wide nature or limited to only one manufacturer. While an attempt was made to obtain data on a variety of make and model sets, the sampling was limited to a single major metropolitan area and adequate representation of any one make or model set was not intended. In fact, the sampling of receivers was so small that only one set was surveyed in some instances. Consequently, data for the entire sample of sets was considered in evaluating the survey results.

Some consolidation and grouping of the receivers was required for tabulation of data and to encourage industry participation in the survey. Industry representatives were interested in participating in the survey, where sets they manufactured or distributed were involved. The grouping of sets facilitated servicing and technical assistance support both from the distributor's and manufacturer's representatives. In some cases, sets are identified to the public only in terms of the brand name of the retail distributors and direct association with a particular manufacturer could only be determined by an inspection and precise identification of the set by model and serial number.

If a brand name survey is desirable, the population of sets selected would have to be statistically representative of the entire industry, both in terms of numbers and geographical distribution. It should also reflect the current as well as the accumulative production of each of the selected manufacturers or brands. Furthermore, within this total population the sample of each brand name would, of necessity, have to be sufficiently large to represent the brand adequately including the specific models and types which could be expected to be significantly different from the standpoint of X-radiation production. In addition, such factors as interchange of components by the manufacturer, interchange of components at the servicing level, and the servicing of a number of brands by a single organization or serviceman, must be clearly identifiable before an evaluation of X-radiation emissions can be made by brand names.

The basic designs of receiver chassis, and the chassis-cabinet combination or model, strongly influenced the observed X-ray conditions. Sets operating at lower picture tube voltages (i.e., 17 to 23 kV) had definitely lower X-ray emission rates than those sets operating at higher kilovoltages. Sets with shunt regulator tubes seemed to have an increased probability of excessive X-radiation emissions. However, proper shielding of high voltage components, either shunt regulator or rectifier tubes, can reduce the probability of X-radiation emission.

The sets as surveyed consisted of some combinations of the original assemblies and replacement components from a variety of sources. The condition of the set at the time of measurement also reflected the servicing carried out by individual manufacturers' representatives, distributors, and independent servicemen.

Survey results confirmed the theoretical and experimental information on the sensitivity of X-radiation production to changes in operating high voltage of receivers. Elevation of operating high voltage settings above rated voltage levels was associated with increased X-radiation emissions; similarly, during corrective servicing decreases in high voltage reduced X-radiation emissions.

It should be noted, however, that some sets operating at levels of 21 kV still emitted excessive X-radiation. This occurred even though the survey instrument tended to record values below the true emission rate at this energy level. Thus all excessive emissions cannot be explained by voltage settings. On the other hand, some of the excessive emissions recorded in the higher operating voltage range are probably due to voltage adjustments and the tendency to record X-radiation emission rates above the true value in this energy range. The degree of change of the instrument reading could only be calculated with precision if some determination of beam quality, such as half-value layers (HVL), could be obtained in the home. However, assuming that a maximum correction factor of 3 for the higher energy levels is applied, excessive X-radiation emissions would still be recorded. The film data indicates more precise definition of the area of the beam and would

generally increase the number of excessive emissions. With the variety of sources, shielding, and beam size further development work is necessary for more precise instrumentation.

CONCLUSIONS

1. Some X-radiation emission was observed in a variety of makes and models of the 1,124 receivers surveyed in the Washington Metropolitan Area.

2. One of the most important findings of the survey is that 856 of the 1,124 receivers surveyed emitted no measurable levels of X-radiation. The survey results demonstrate that the industry has produced color television sets that can be operated well within the National Council on Radiation Protection and Measurements' recommendation and in most instances with X-radiation emission levels approaching normal background radiation in homes.

3. The primary sources of X-ray emissions are (1) the high voltage shunt regulator tube, (2) the high voltage rectifier tube, and (3) the picture tube.

4. The operating high voltage for television receivers demonstrably affects production and emission of X-radiation from components.

5. It is possible to reduce X-radiation emissions through service adjustments, including replacement of shunt regulator or high voltage rectifier tubes, and reduction of the operating high voltage.

6. The survey technique did not provide data to support a valid association of observed X-radiation conditions with individual brand name or manufacturer on a nationwide basis.

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TABLE I

X-RADIATION EMISSION FROM COLOR TELEVISION RECEIVERS

GROUP*	SETS SURVEYED	SETS WITH X-RADIATION AT OR ABOVE 0.04 mR/hr	SETS WITH X-RADIATION AT OR ABOVE 0.5 mR/hr
A	360	78	20
B	162	58	19
C	100	7	0
D	75	32	4
E	72	5	0
F	71	18	1
G	69	23	10
H	45	3	0
I	33	13	1
J	30	5	0
K	19	0	0
L	18	1	0
M	16	0	0
N	15	3	1
O	13	13	8
P	7	3	0
Q	6	1	0
R	4	0	0
S	2	2	1
T	2	2	1
U	2	0	0
V	1	0	0
W	1	0	0
X	1	1	0
TOTAL	1,124	268	66

* Some standardization of terminology and grouping of sets was essential for tabulation and interpretation of results by manufacturer, brand name, distributor, or retailer dealer. The term "brand" can be related to the manufacturer or the name underwhich the set is marketed.

TABLE II

DISTRIBUTION OF COLOR TV RECEIVERS
BY THE X-RADIATION EXPOSURE RATE

X-RADIATION EXPOSURE RATE mR/hr	NUMBER RECEIVERS IN RANGE
< 0.040	856
0.040 - 0.074	52
0.075 - 0.124	38
0.125 - 0.249	68
0.250 - 0.499	44
0.500 - 0.999	26
1.000 - 1.999	23
2.000 - 3.749	5
3.750 - 7.499	5
7.500 -12.499	5
> 12.500	2

TOTAL SETS - 1,124

TABLE III

LOCATION OF MAXIMUM X-RADIATION EXPOSURE RATES
ON HOME COLOR TV RECEIVERS

X-radiation Exposure Rates mR/hr	Number of Sets by Location of the Highest Exposure Rate Measurement*						
	Bottom	Left	Top	Front	Right	Back	Total
0.040 - 0.074	8	7	12	14	0	11	52
0.075 - 0.124	6	4	9	11	0	8	38
0.125 - 0.249	2	23	14	9	0	20	68
0.250 - 0.499	2	14	4	8	1	15	44
0.500 - 0.999	6	7	2	3	1	7	26
1.000 - 1.999	3	6	0	5	0	9	23
2.000 - 3.749	0	2	0	1	0	2	5
3.750 - 7.499	0	2	0	2	0	1	5
7.500 -12.499	1	2	0	1	0	1	5
> 12.500	1	1	0	0	0	0	2
TOTAL	29	68	41	54	2	74	268

* A number of sets had the same exposure-rate on more than one side. The priority for placement in the table is the following: front, left, top, back, bottom, and right. "Left" is the set surface on the viewer's left.

TABLE IV

NUMBERS OF COLOR TV RECEIVERS BY X-RADIATION EXPOSURE RATE AND OPERATING HIGH VOLTAGE

X-radiation Exposure Rate mR/hr	Operating High Voltage (kilovolts)																	
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOTAL
< 0.040	47	14	18	27	46	73	90	121	83	39	16	6	1	1	0			582
0.040 - 0.074	0	0	1	0	2	4	6	6	10	6	5	0	0	0	0			40
0.075 - 0.124	0	0	0	1	2	1	3	3	5	10	5	0	1	1	0			32
0.125 - 0.249	0	0	0	2	7	7	7	7	8	7	5	5	0	0	0			55
0.250 - 0.499	0	0	0	2	3	0	3	7	3	6	6	4	2	0	0			36
0.500 - 0.999	0	0	0	1	0	3	4	4	3	4	4	1	0	1	1			26
1.000 - 1.999	0	0	0	0	0	1	3	5	4	2	0	2	1	3	0			21
2.000 - 3.749	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0	1		5
3.750 - 7.499	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	1	4
7.500 -12.500	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	5
> 12.50	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2
TOTALS	47	14	19	33	60	89	116	156	119	76	42	18	8	7	1	1	2	808*
% exceeding 0.5 mR/hr	0	0	0	3.0	0	4.5	6.0	7.7	8.4	10.5	11.9	16.7	50.0	71.4	100.0	100.0	100.0	

* Operating high voltage measurements were not made on 316 receivers. Three of these receivers had radiation emissions above 0.5 mR/hr.

TABLE V

Household Members by Age, by Normal Viewing Distance and Hours Per Week Viewing Time

	TOTAL	DISTANCE IN FEET					
		UNDER 4 FT.	4-7 FT.	8-11 FT.	12-15 FT.	16+ FT.	NOT INDICATED
All Ages (Years)	2,311	84	659	969	484	71	44
Hours Per Week			(Number of Persons)				
15 and under	1,061	49	290	442	225	39	16
16-30	845	24	239	376	179	19	8
31+	380	11	127	148	78	13	3
Not Indicated	25	0	3	3	2	0	17
Under 15 Years Old	547	48	280	150	39	6	24
Hours Per Week							
15 and under	198	22	100	53	10	5	8
16-30	219	18	104	64	25	1	7
31+	120	8	74	33	4	0	1
Not Indicated	10	0	2	0	0	0	8
15-44 Years Old	1,049	23	232	497	255	30	12
Hours Per Week							
15 and under	536	16	123	242	134	14	7
16-30	360	5	78	189	79	8	1
31+	149	2	30	65	42	8	2
Not Indicated	4	0	1	1	0	0	2
45 Years Old and Over	715	13	147	322	190	35	8
Hours Per Week							
15 and under	327	11	67	147	81	20	1
16-30	266	1	57	123	75	10	0
31+	111	1	23	50	32	5	0
Not Indicated	11	0	0	2	2	0	7

TABLE VI

X-RADIATION EMISSION LEVELS FROM COLOR TELEVISION RECEIVERS
BY LOCATION, PROBABLE SOURCE AND OPERATING KILOVOLTAGE
BASED ON SURVEY INSTRUMENTATION AND RADIOGRAPHIC FILM MEASUREMENTS

Receiver Case Number[1]	Receiver Operating Voltage (kV)	Probable Source of X-radiation	Location Film on Receiver	Time of Film Exposure (hr)	X-radiation Exposure Rates in mR/hr	
					Film	Instrument
1a	-	Picture[2]	Left	61.40	0.12	0.10
1b	-	Picture	Right	61.40	0.13	0.11
1c	-	Picture	Top	61.40	0.15	0.11
2	27.6	Rectifier	Bottom	30.50	0.14	1.10
3a	-	-	Back	(29.00)[3]	0.15	0.14
3b	-	-	Back	(29.00)	0.22	0.14
4	27.0	Rectifier	Back	(78.00)	0.17	0.19
5	29.0	Shunt or Rectifier	Left	28.40	0.17	0.62
6	24.0	Picture	Top	(60.00)	0.20	0.28
7	28.5	Picture	Back	49.50	0.22	0.60
8	-	Picture	Top	55.50	0.33	0.10
9	25.5	Rectifier	Left	64.50	0.36	0.21
10	23.8	Picture	Back	43.20	0.43	0.83
11	27.0	Rectifier	Back	23.00	0.43	0.10
12	26.5	Rectifier	Left	30.50	0.44	0.19
13	24.5	Rectifier	Back	(43.00)	0.52	0.19
14a	25.0	Shunt	Left	(27.50)	0.80	0.50
14b	25.0	Shunt	Back	(8.00)	3.65	3.25
15	31.0	Shunt	Back	24.80	0.90	1.10

TABLE VI

Receiver Case Number	Receiver Operating Voltage (kV)	Probable Source of X-radiation	Location Film on Receiver	Time of Film Exposure (hr)	X-radiation Exposure Rates in mR/hr	
					Film	Instrument
16	26.0	Shunt	Bottom	(63.50)	0.92	0.88
17a	30.5	Shunt & Pict.	Top	61.30	1.20	2.25
17b	30.5	Shunt & Pict.	Left	61.30	3.17	2.25
17c	30.5	Shunt & Pict.	Back	61.30	12.80	7.50
18	29.0	Shunt	Left	27.50	1.34	0.65
19	30.5	Picture	Left	(10.00)	1.40	2.25
20	26.8	Shunt	Left	(35.00)	1.50	0.20
21a	25.0	Shunt	Back	(49.00)	1.60	1.50
21b	25.0	Shunt	Left	(49.00)	2.38	0.30
22	25.0	Shunt	Front	85.00	1.76	0.63
23	25.5	Rectifier	Left	(65.50)	1.84	1.00
24a	30.0	Picture	Top	5.08	1.92	1.25
24b	30.0	Shunt & Pict.	Back	5.08	94.50	>12.50
24c	30.0	Shunt & Pict.	Back	5.08	181.00	>12.50
25	27.0	Shunt	Back	(133.00)	2.03	1.40
26	27.0	Shunt	Back	(22.30)	2.06	1.50
27	34.0	Picture	Front	(5.25)	2.54	5.00
28	25.0	Shunt	Left	(64.00)	2.50	1.10
29	33.5	Shunt	Back	5.97	3.10	2.50
30	25.1	Shunt	Left	(12.50)	3.50	1.10
31a	26.5	Shunt & Pict.	Back	(13.50)	3.63	0.88
31b	26.5	Shunt & Pict.	Left	(13.50)	4.23	1.12
32	24.0	Shunt	Back	51.60	4.09	1.62

TABLE VI

-3-

Receiver Case Number [1]	Receiver Operating Voltage (kV)	Probable Source of X-radiation	Location Film on Receiver	Time of Film Exposure (hr)	X-radiation Exposure Rates in mR/hr	
					Film	Instrument
33	24.2	Shunt	Back	(17.00)	4.60	0.75
34	26.5	Shunt	Back	22.50	5.80	1.00
35	26.0	Shunt	Back	8.10	6.30	1.10
36	26.2	Shunt	Back	5.50	7.61	2.50
37	25.5	Shunt	Left	(4.00)	7.61	2.60
38	26.0	Shunt	Bottom	24.00	9.81	0.81
39	25.5	Shunt	Left	(8.50)	10.60	3.75
40	24.1	Shunt	Back	(27.60)	11.40	1.10
41	31.0	Shunt & Pict.	Left	(21.00)	24.40	11.20
42	27.0	Shunt	Left	(6.33)	29.50	3.75
43	28.5	Shunt	Left	11.00	47.40	10.00
44	23.5	Shunt	Back	13.90	51.00	1.25
45	26.2	Shunt	Bottom	9.58	89.20	8.80
46	23.0	Shunt	Left	0.19	97.10	0.55
47	28.6	Shunt	Bottom	(1.85)	100.00 [4]	12.50
48	26.0	Shunt	Bottom	(0.88)	369.00	>12.50
49a	29.0	Picture	Left	Exposure Time Not Recorded	-	0.40
49b	29.0	Picture	Top	Exposure Time Not Recorded	-	0.70
50a	31.0	Shunt & Pict.	Back	Exposure Time Not Recorded	-	1.25

TABLE VI

-4-

Receiver Case Number[1]	Receiver Operating Voltage (kV)	Probable Source X-radiation	Location Film on Receiver	Time of Film Exposure (hr)	X-radiation Exposure Rate in mR/hr	
					Film	Instrument
50b	31.0	Shunt & Pict.	Left	Exposure Time Not Recorded	-	1.50
51a	27.0	Picture	Back	Insufficient Exposure Time	-	0.50
51b	27.0	Picture	Top	Insufficient Exposure Time	-	0.51
51c	27.0	Picture	Right	Insufficient Exposure Time	-	0.53
51d	27.0	Picture	Left	Insufficient Exposure Time	-	0.53
52	24.5	-	Improperly Located Film	Insufficient Exposure Time	-	0.63
53	27.0	Rectifier	Left	Exposure Time Not Recorded	-	0.87
54	-	Picture	Front	Insufficient Exposure Time	-	1.10
55	27.5	Shunt	Left	Insufficient Exposure Time	-	4.20

1) Subscripts indicate where more than one film was used

2) Picture refers to picture tube

3) Exposure time estimated from record kept by set owner or by surveyor are shown in parentheses

4) The radiographic film was exposed on receiver 47 at the minimum brightness condition. The receiver was emitting X-rays at greater than 0.5 mR/hr for the normal operating condition.

TABLE VII

HIGHEST X-RADIATION EXPOSURE RATE FOR COLOR TV RECEIVERS
DISTRIBUTED BY DATE OF PURCHASE

X-radiation Exposure Rate mR/hr	Not Recorded	1955-1962	1963	1964	1965	1966	1967	1968	TOTAL
< 0.040	31	34	16	45	103	240	385	2	856
0.040- 0.074		2		3	7	22	18		52
0.075- 0.124			2		7	14	15		38
0.125- 0.249	2	2	2	2	15	20	25		68
0.250- 0.499			1	2	14	14	13		44
0.500- 0.999	2		1	2	2	11	8		26
1.000- 1.999				3	7	7	6		23
2.000- 3.749						3	2		5
3.750- 7.499					1	1	3		5
7.500-12.499					1	4			5
> 12.500				1		1			2
TOTALS	35	38	22	58	157	337	475	2	1,124